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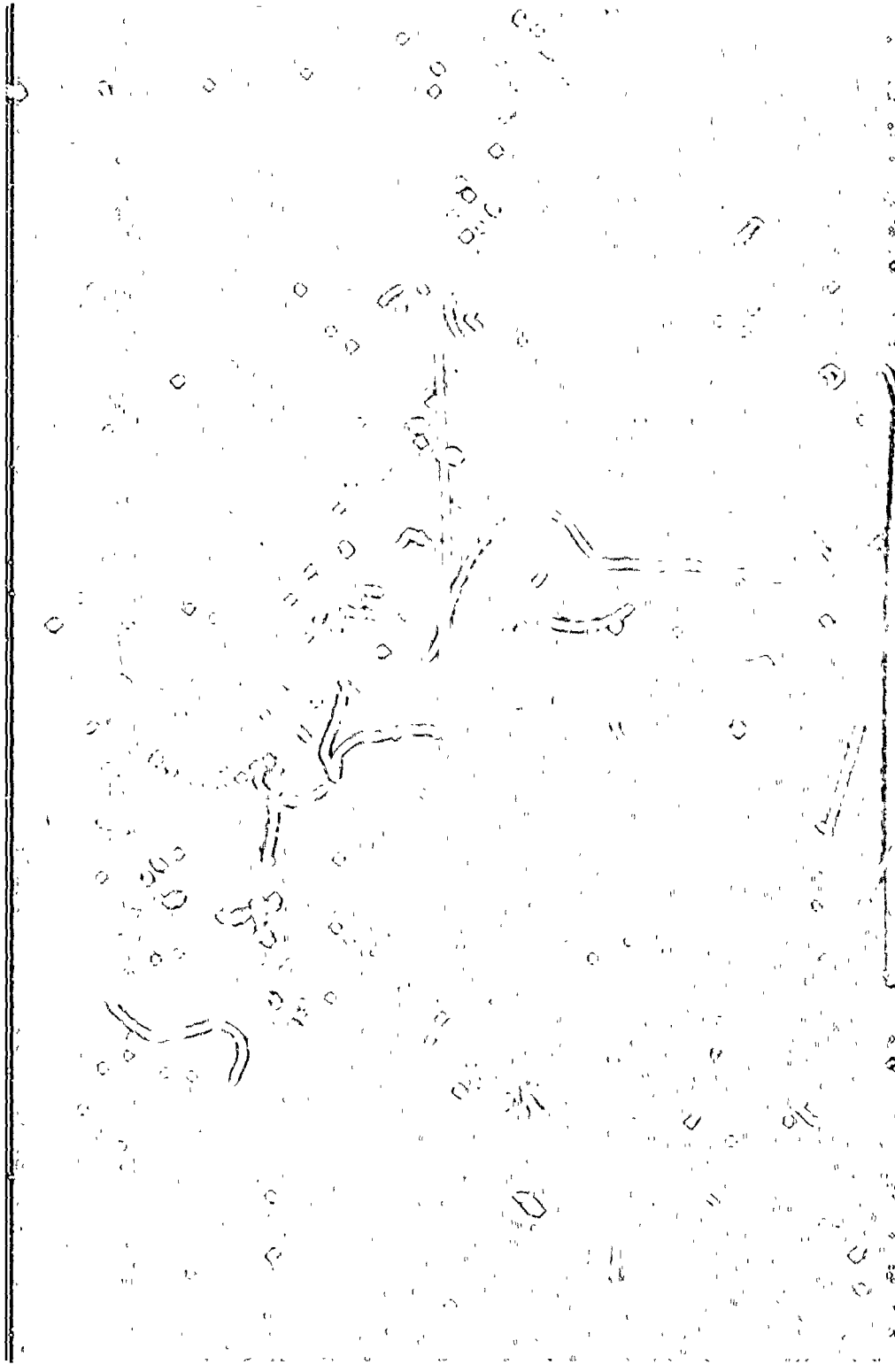

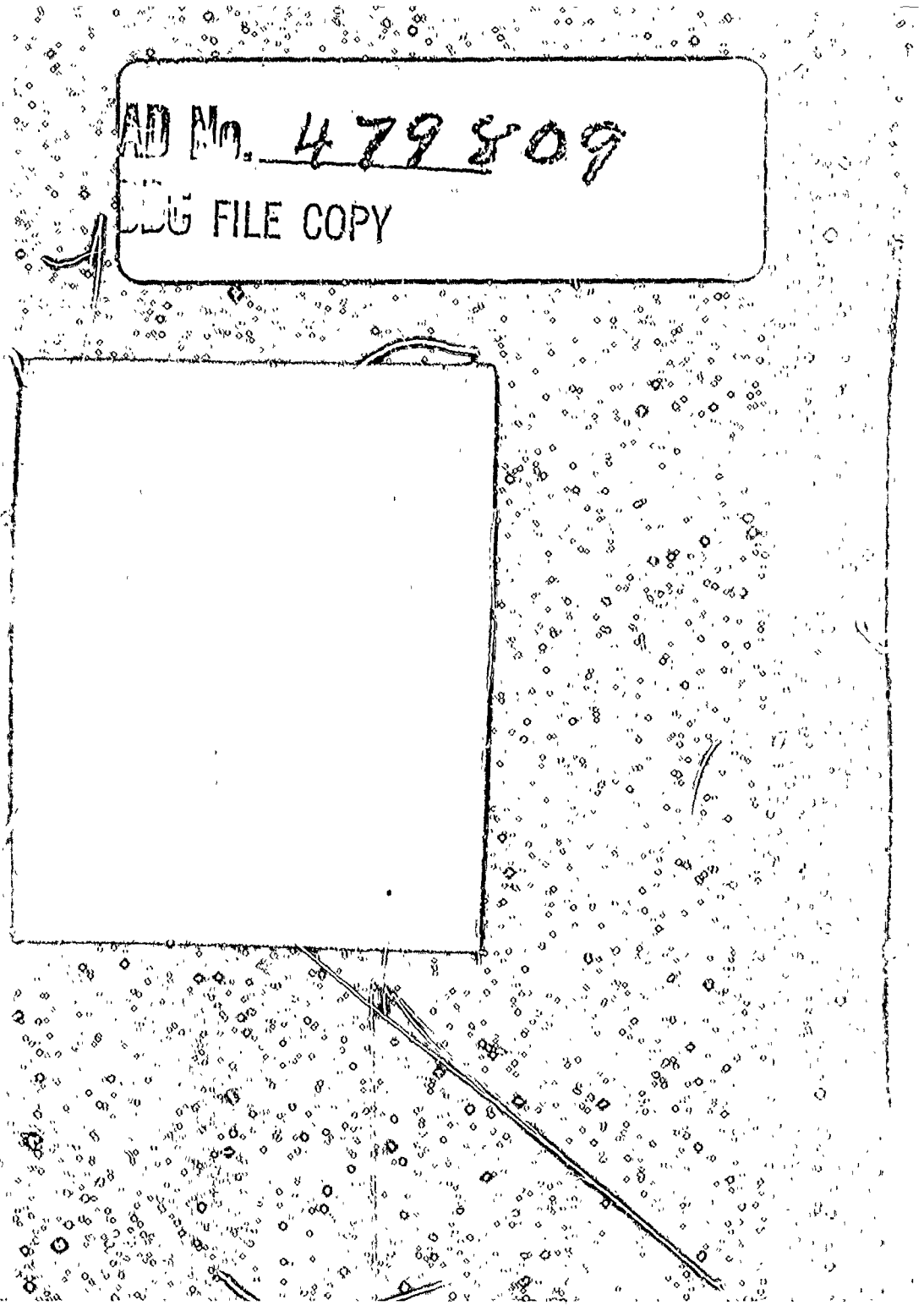

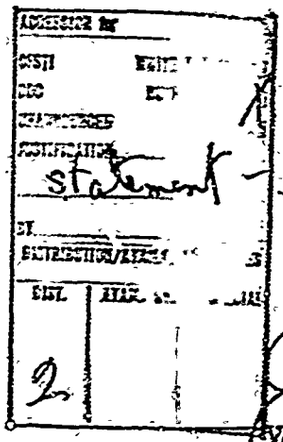

(6) Research on Experimental Heat of Vaporization and Enthalpy Measurements of Oxygen-Nitrogen-Argon Mixtures.

(9) Quarterly Progress Report No. 7, 7 Oct-31 Dec 65,

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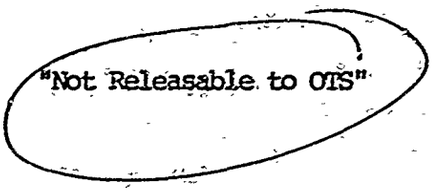
FOREWORD

This report is the seventh of a series of written Quarterly Progress Reports which precede the Final Technical Documentary Report. This report summarizes the work done in connection with the experimental determination of enthalpy of oxygen, nitrogen and argon mixtures from October 7, 1965 to December 31, 1965.



ABSTRACT

This is the Seventh Quarterly Progress Report on the experimental determination of latent heats and enthalpy data of oxygen-nitrogen-argon three-component mixtures. Two hundred and one runs have been made during the past three-month period making a total of 2458 enthalpy points since the beginning of the project. This report summarizes the enthalpy data obtained during the past quarter.

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I. INTRODUCTION

This is the Seventh Quarterly Progress Report on the experimental determination of latent heats and enthalpy data of oxygen-nitrogen-argon three-component mixtures. Forty mixtures are being studied at pressure levels ranging from 0.1 to 25 atm over the range of compositions from 100% oxygen to 100% nitrogen and from 0.0% to 5.0% argon in the temperature range 100°R to 400°R. Details of the experimental equipment and the particular points to be measured are given in Quarterly Progress Report I[1]. Modifications to the equipment are reported in Quarterly Progress Reports II[2], III[3], IV[4], V[5], and VI[6].

This report summarizes the enthalpy data obtained during the past quarter.

II. OPERATION AND MODIFICATIONS

During this quarter continued experimental difficulties were experienced during enthalpy measurements on sub-cooled liquid samples in the flow calorimeter. While earlier modifications of the cold exit piping had improved system stability, further modifications performed during this quarter successfully solved the stability problem. Meaningful data are being obtained routinely at 125°R down to about 1 atmosphere pressure. The measurements program is again in full swing to complete the low temperature measurements in the flow calorimeter.

During a routine calibration of the wet test meters, a significant change in calibration was found for the process stream meter. The problem was identified as an oil leak in the meter. The problem was remedied and the affected enthalpy data points were rerun. Other than this, the calibration of the meters show random variations which are less than ±0.2%. This is consistant with the variations during previous quarters.

III. EXPERIMENTAL DATA

Two hundred and one enthalpy runs have been made in the flow calorimeter during the past quarter, making a total of 2458 runs since the beginning of the project. Due to malfunctioning of a wet test meter, one set of runs (sixty-six points) was repeated after meter repair. Therefore, one hundred and thirty-five valid data points were obtained. Two gas mixtures were studied. The nominal compositions are given in Table I along with the actual compositions as determined by gas chromatography.

The experimental enthalpy data are presented in Tables 1 and 2. In these tables ΔH is the measured enthalpy change and $H_{560}-H_T$ is the enthalpy normalized to a common inlet temperature of 560°R as described in Quarterly Report II. Although figures of the plotted data are not presented, the agreement and consistency is as good as the data plotted in the previous Quarterly Reports.

Table 1

GAS ANALYSES

Nominal Composition			Actual Composition Before Use			Actual Composition After Use			Tables Containing Experimental Enthalpy Data
% N_2	% Ar	% O_2	% N_2	% Ar	% O_2	% N_2	% Ar	% O_2	
9.6	4.0	86.4	9.7	4.05	86.85	10.48	4.00	85.52	2
9.5	5.0	85.5	10.17	4.38	85.45	10.00	4.94	85.07	3

Table 2

EXPERIMENTAL ENTHALPY DATA FOR
4% Ar in 10% N_2/90% O_2
MEASURED IN FLOW CALORIMETER

Run No.	Pressure Atm.	Inlet Temp. °R	Outlet Temp. °R	$(H_T - H_{460})$ Btu/lb-Mole	$(H_{560} - H_{460})$ Btu/lb-Mole
2390	25.01	562.3	400.0	1191	1175
2391	20.01	562.7	399.9	1172	1153
2392	15.01	562.9	400.0	1157	1136
2393	10.02	563.3	400.1	1149	1126
2394	7.01	563.6	399.9	1141	1116
2395	5.01	563.9	400.0	1138	1111
2396	2.01	564.9	400.0	1140	1106
2397	1.00	565.2	399.8	1138	1102
2398	0.50	565.6	399.8	1135	1096
2399	0.10	565.5	400.0	1139	1102
2400	25.00	562.2	350.2	1588	1565
2401	20.00	562.6	350.1	1563	1544
2402	14.99	563.0	350.2	1537	1515
2403	10.00	563.4	350.2	1506	1482
2404	6.99	563.5	350.2	1491	1467
2405	24.99	562.8	300.2	2008	1987
2406	19.99	563.2	300.2	1962	1939
2407	14.99	563.4	300.3	1923	1899
2408	9.99	563.7	300.1	1889	1863
2409	6.99	563.8	300.3	1856	1829
2410	4.99	564.0	300.1	1845	1817
2411	1.99	564.3	300.1	1828	1797
2412	1.00	563.2	300.2	1819	1797
2413	0.49	563.8	300.3	1815	1788
2414	0.10	564.2	300.2	1815	1785
2415	14.97	561.6	250.0	2340	2328
2416	9.98	561.7	250.2	2267	2255
2417	6.98	561.6	250.3	2231	2217
2418	4.98	561.9	250.4	2209	2195
2419	1.98	562.1	200.0	2539	2525
2420	1.00	562.7	200.0	2526	2507
2421	0.50	562.4	200.0	2516	2499
2422	0.10	563.2	200.0	2510	2488
2423	24.98	561.7	247.3	2572	2559
2424	19.98	561.1	239.1	2551	2543
2425	14.99	559.6	228.7	2546	2549
2426	9.99	560.7	215.5	2569	2564
2427	6.99	561.1	206.6	2583	2576
2428	4.99	561.5	200.5	2597	2587
2429	1.99	562.7	179.9	2697	2678
2430	1.00	558.4	174.6	2678	2689
2431	0.50	559.0	166.4	2728	2735
2432	0.09	557.4	150.1	2857	2875
2433A	25.00	557.5	150.1	5667	5685
2433B	25.00	560.8	150.1	5786	5780
2433C	25.00	560.9	150.2	5787	5781

Table 2 (continued)

Run No.	Pressure Atm.	Inlet Temp. °R	Outlet Temp. °R	(ΔH) Btu/lb-mole	($H_{560}-H_T$) Btu/lb-mole
2433D	25.00	559.4	150.1	5677	5681
2434A	20.00	559.2	150.0	5668	5674
2434B	20.00	561.9	150.2	5869	5855
2435	14.99	555.8	150.1	5716	5746
2436	9.99	554.1	150.1	5737	5779
2437	6.99	554.0	150.0	5751	5794
2438	4.99	553.0	149.9	5816	5866
2439	4.99	554.7	190.3	5216	5253
2440	7.01	555.0	200.0	5125	5153
2441	10.01	556.9	210.1	4944	4966
2442	15.00	557.2	223.5	4725	4745
2443	20.00	558.3	233.8	4542	4555
2444	25.01	559.2	242.1	4383	4389
2444A	25.00	558.7	242.2	4396	4405
2445	25.00	559.0	199.8	5093	5106
2446	20.00	558.6	199.8	5070	5080
2447	25.00	560.1	244.4	3501	3501
2448A	24.99	562.1	124.8	6221	6205
2449	19.99	561.5	124.8	6197	6186
2450	14.99	561.9	124.8	6208	6195
2448B	25.01	557.6	124.9	6052	6070
2451	10.01	555.9	124.8	6196	6226
2452	7.01	554.0	124.7	6272	6315
2405A	24.99	559.7	302.0	1988	1991
2445A	24.99	555.2	203.5	4997	5031
2445B	24.99	554.6	204.8	5028	5067
2448C	25.01	556.8	125.3	6473	6496
2448D	24.99	555.7	129.4	6058	6089
2448E	24.99	556.0	128.9	6088	6117
2454	1.99	557.6	130.1	6093	6110
2455	0.99	558.7	129.9	6242	6251
2456	0.49	557.9	129.7	6277	6292
2452A	7.01	548.9	126.8	6345	6423
2453	5.01	550.5	125.8	6478	6545
2454A	2.01	559.1	129.8	6248	6254
2457	7.01	559.0	203.4	3816	3823
2458	15.01	559.5	226.5	3814	3818

Table 3

EXPERIMENTAL ENTHALPY DATA FOR
5% Ar in 10% H_2/90% O_2
MEASURED IN FLOW CALORIMETER

Run No.	Pressure Atm.	Inlet Temp. °R	Outlet Temp. °R	(ΔH) Btu/lb-mole	$(H_{560}-H_T)$ Btu/lb-mole
2324	25.00	564.1	399.5	1110	1091
2325	20.00	564.1	400.0	1072	1043
2326	14.99	564.3	399.8	1074	1044
2327	10.00	564.2	400.0	1059	1030
2328	7.00	564.4	400.0	1066	1035
2329	5.00	564.3	399.7	1041	1011
2330	2.00	564.9	399.8	1047	1014
2331	1.00	565.2	400.0	1061	1025
2332	0.50	564.5	399.9	1034	1003
2333	0.11	565.2	399.8	1034	998
2334	25.00	563.1	350.0	1501	1479
2335	20.00	563.3	350.2	1502	1478
2336	15.00	562.1	350.3	1498	1484
2337	10.00	562.0	350.1	1456	1442
2338	7.00	562.1	350.2	1496	1482
2339	25.00	561.5	300.3	1996	1985
2340	20.00	561.7	300.4	1948	1936
2341	15.00	562.3	300.4	1906	1891
2342	10.01	562.3	300.4	1879	1863
2343	7.01	562.3	300.2	1860	1844
2344	5.01	562.9	300.0	1851	1831
2345	2.01	563.8	300.2	1838	1812
2346	1.00	564.7	300.2	1848	1816
2347	0.50	564.9	300.2	1840	1806
2348	0.10	565.3	300.1	1838	1802
2349	15.00	563.1	249.9	2345	2323
2350	10.01	562.9	249.9	2270	2250
2351	7.01	560.9	250.2	2225	2219
2352	5.01	560.9	250.2	2200	2193
2353	2.01	562.7	200.1	2542	2523
2354	1.00	563.7	199.9	2536	2511
2355	0.50	564.0	199.8	2535	2508
2356	0.10	564.5	200.0	2528	2497
2357	25.01	563.2	247.3	2581	2558
2358	20.01	562.5	238.9	2558	2540
2359	15.00	562.4	228.7	2558	2541
2360	10.01	562.7	215.4	2576	2556
2361	7.01	561.8	206.3	2585	2573
2362	5.01	562.1	200.4	2593	2579
2363	2.01	563.4	179.8	2701	2677
2364	1.00	564.2	175.3	2712	2682
2365	0.50	564.6	166.4	2779	2747
2366	25.02	561.6	124.8	6129	6117
2367	20.02	561.1	124.9	6110	6102

Table 3 (continued

Run No.	Pressure Atm.	Inlet Temp. °R	Outlet Temp. °R	(ΔH) Btu/lb-mole	($H_{560}-H_T$) Btu/lb-mole
2368	15.02	560.7	124.8	6167	6162
2369	10.03	559.6	125.0	6111	6113
2370	7.02	559.7	124.7	6199	6202
2371	5.02	559.9	124.7	6201	6202
2372	0.10	567.[illegible]	146.[illegible]	3015	2965
2373	25.02	562.6	200.1	5059	5040
2374	20.01	558.6	200.1	5037	5047
2375	25.01	560.5	150.0	5657	5654
2376	20.01	560.0	150.0	5672	5672
2377	15.01	558.9	150.1	5700	5708
2378	10.02	557.7	150.1	5718	5734
2379	7.02	558.0	150.1	5725	5739
2380	5.02	558.3	150.1	5823	5835
2381	5.02	559.9	190.3	5235	5236
2382	7.02	560.2	199.5	5084	5083
2383	10.02	561.1	210.1	4921	4914
2384	15.01	561.5	223.6	4743	4733
2385	20.01	562.1	233.9	4531	4516
2386	25.01	563.0	242.1	4385	4364
2387	25.01	561.2	244.0	3772	3763
2388	15.01	560.3	225.5	3649	3647
2389	7.01	560.8	202.0	3782	3777

IV. SUMMARY

During the past quarter, 201 enthalpy runs have been made making a total of 2458 points measured since the beginning of the project.

Considerable experimental difficulties were encountered and overcome during this quarter, a fact which explains the relatively small number of valid data points obtained. An oil leak in a wet test meter necessitated the repeat of one set of runs (66 points). Exploratory tests have lead to modifications of the cold exit piping which permit valid measurements to be made in the sub-cooled liquid region. The apparatus operates stablely at 125°R down to 1 atmosphere. The measurements program is again in full swing to complete the low temperature tests in the flow calorimeter.

V. REFERENCES

1. W. H. Lien and G. M. Wilson, "Research on Experimental Heat of Vaporization and Enthalpy Measurements of Oxygen-Nitrogen-Argon Mixtures", Quarterly Progress Report I, Contract No. AF 33(615)-1332, July 1964.

2. W. H. Lien and G. M. Wilson, "Research on Experimental Heat of Vaporization and Enthalpy Measurements of Oxygen-Nitrogen-Argon Mixtures", Quarterly Progress Report II, Contract No. AF 33(615)-1332, October 1964.

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